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The Selection of Commercial Astronauts for Suborbital Spaceflight

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When SpaceShipOne won the Ansari X-Prize in 2004, it launched the commercial space tourism industry. In 2007 Burt Rutan said, “We think that 100,000 people will fly by 2020” (Rutan, 2007). This will create a need for qualified crews to operate these spacecraft. The purpose of this qualitative, exploratory study was to investigate the possible selection criteria of these crews. Data was collected from telephone and email interviews with four U.S.-suborbital space tourism companies and Purdue University's astronaut alumni network. Grounded Theory and Truth and Reality Testing were used as the theoretical framework for data analysis. The data gathered suggests that the commercial astronaut should have at least a Bachelor's degree in engineering, have a test pilot background with thousands of hours of pilot-in-command time in high performance jet aircraft, be confident yet humble, and have a fundamental understanding of his/her spacecraft, including spacecraft trajectories, and emergency procedures.

The Ansari Foundation established the Ansari X-Prize which was a prize of $10 million U.S. to spur innovation to create a cheaper, reusable launch system which would allow economies of scale to lower the cost of space access. Scaled Composites' test pilot Mike Melvill became the first commercial astronaut when he flew SpaceShipOne into space at an altitude of 100 km in 2004. Melvill had 23 years of test pilot experience and flown 10 first flights of Burt Rutan's aircraft. Brian Binnie, another Scaled Composites test pilot, flew SpaceShipOne on its historic flight to win the X-Prize in 2004. His flight reached an altitude of 112 km. Binnie flew for the United States Navy for 21 years and graduated from the U.S. Naval Test Pilot School. These two men have been the only current commercial astronauts at the time of this writing (Ansari X-Prize Foundation, 2010).

Review of Government Astronaut Selection

Deke Slayton, one of National Aeronautics and Space Administration's (NASA) first astronauts and head of astronaut selection from 1963 – 1972, said the selection of an astronaut is a complex task that may take up to two years to complete. Slayton wrote, “I had already developed a point system that we used in making the final evaluations on astronaut candidates. There were three parts: academic, pilot performance, and character/motivation” (Slayton, 1994, p. 133). Each has been a separate, independent skill that intertwines with the others to create a well-rounded candidate. These three parts were used to develop the research questions used in this study.

Early astronauts from NASA had to have at least a Bachelor's degree in a related engineering field such as aeronautical or astronautical engineering (Smith, 2005). NASA also wanted professionals who were stable and who had been screened for security because the early space program was a national security interest (Shepard, 1994). For subsequent astronaut groups, the selection criteria was relaxed slightly to a Bachelor's degree in a physical science or engineering field. Currently, NASA requires a minimum of a Bachelor's degree in science or related engineering for astronaut applicants with more emphasis placed on a Master's degree or Doctorate degree (Cernan, 1999).

Similarly, Soviet/Russian Federal Space Agency (RKA) cosmonauts (astronauts) were required to have a technical engineering degree (Gagarin, 2008). However, the RKA was less interested than NASA in the particular type of degree that their astronauts earned. They accepted various types of engineering degrees as long as they could be somehow related to the space program (Linenger, 2000). Currently, the RKA only accepts astronaut applicants who have a technical engineering degree; a science degree does not qualify (Gagarin, 2008). The desire for highly educated people has also been common to the European Space Agency (ESA). Their astronaut candidates should have a minimum of a Bachelor's degree in a technical, scientific or engineering field. A Master's degree with several years of related experience prior to application has also been preferred (Messerschmid et al., 2003).

The spaceflight industry has been highly competitive and as a result the quality of academic preparedness has been important. Gene Cernan, a Purdue University graduate who walked on the Moon during Apollo 17, wrote “Receiving a B instead of a B+ in some college course years earlier might be reason enough to pick the other guy” (Cernan, 1999, p.58).

The RKA was the first agency to launch an astronaut into space in 1961; NASA followed with a suborbital spaceflight a few weeks later (NASA, 1963; RKA, 2009). The early astronauts from both agencies were explorers

in the brand new field of spaceflight. Both agencies decided to select military test pilots for the first group of astronauts because of their considerable piloting experiences in experimental vehicles (Clark, 1988). Early spacecraft were highly experimental and fraught with danger because the challenges of flying in space were relativity unknown and the technology to travel in space was in its infancy (Harvey, 2004).

NASA wrote, "The astronauts were first and foremost test pilots, men accustomed to flying along in the newest, most advanced, and most powerful vehicles this civilization had produced. They were talented specialists who loved to fly high-performance aircraft and who had survived the natural selection process in their profession" (NASA, 1963, p. 1). Flying experimental vehicles was dangerous and approximately six test pilots died each year as a result of testing them (Slayton, 1994). The pilots who did survive were ideal for the space program because they were well-rounded pilots with experience related to the interdisciplinary aspects of flying (Borman, 1988).

Unforeseen problems could occur that might require an astronaut to think quickly in unfamiliar situations. Test pilots regularly work and operate in such environments (Freeman, 2000). On the first flight of suborbital flight of SpaceShipOne there were several anomalies. After engine ignition, the vehicle experienced a failure of an electric trim tab which caused it to roll a total of 29 times at speeds ranging from Mach 1 to Mach 3 at altitudes in excess of 200,000ft (Scaled_Composites, 2010). SpaceShipTwo, though built on existing technology, has been a highly experimental vehicle.

The quality and type of person selected as a commercial astronaut has also been very important. The astronauts are flying high performance vehicles in extremely hostile environments with little room for error. The physical and physiological stresses are immense (NASA, 1963). An astronaut needs to be calm under pressure and quick thinking (Freeman, 2000). The qualities of test pilots were also very similar. Shepard wrote, "Esprit de corps, pride, honor, dedication, skill, and courage were all qualities required of the men who would become astronauts" (Shepard, 1994, p. 50).

Methodology

This research project was a qualitative study conducted to contribute to the body of knowledge as it relates to the selection of commercial astronauts for suborbital spaceflight. The study was exploratory because the space tourism industry is less than 10 years old and there are presently only two commercial astronauts. Sekaran wrote, "An exploratory study is undertaken when not much is known about the situation at hand, or no information is available on how similar problems or research issues have been solved in the past" (2003, p. 119).

Wiggins said, "Qualitative research techniques are typically applied in situations where little is known about a particular domain" (1999, p. 164). Furthermore, qualitative research methods are useful for "new fields of study where little work has been done, few definitive hypotheses exist and little is known about the nature of the phenomenon" (Patton, 2002, p.193).

Theoretical Framework

The theoretical framework describes and defines the gathering and interpretation of data in this study as it relates to qualitative research and is a key aspect of such research (Sekaran, 2003). The qualitative research technique Grounded Theory was used as a theoretical framework for the study. It was developed by Barney Glaser and Anselm Strauss as a research method to create a theory from the generalization of recorded data rather than test an established theory (Sekaran, 2003). Grounded Theory allows for opened-ended interviews which are useful to gather as much data about a certain process as possible without being constrained to set answers. A key aspect of Grounded Theory is the bias and credibility of the researcher because the researcher gathered, analyzed and interpreted data based upon his experience and knowledge of the subject. Grounded theory was the fundamental framework used in this study, Truth and Reality Testing was used as a secondary framework to backup data gathered with Grounded Theory. Truth and Reality Testing was useful to determine how data gathered related to what is going on in the real world (Patton, 2002). The researcher used recorded phone interviews and email correspondence to collect data. The researcher was able to establish a rapport with the individual prior to the actual interview. The individuals representing the suborbital space companies were co-founders, vice presidents of engineering/research, former NASA astronauts, or test pilots with actual suborbital spaceflight experience.

Data Analysis

Data analysis of qualitative studies was unique to the study and theoretical framework being used. Patton wrote, "Qualitative analysis transforms data into findings. No formula exists for that transformation" (2002, p. 433).

The analysis of data associated with the study is heavily dependent upon the theoretical framework used within the study and with the bias and credibility of the researcher himself (Patton, 2002). Like quantitative research, there exists a set of tools to allow the researcher to conduct his/her data analysis with credibility (Glaser & Strauss, 1967).

Grounded Theory is one such tool which is based upon the ability of the researcher to fundamentally understand the data gathered and transform the data into meaningful information. The resulting assertions and/or theory generated from the data is the result of the data analysis process. There are several distinct steps in the Grounded Theory process in which the data/interview transcripts were read and analyzed a total of seven times.

During data analysis, the interview transcript was read completely several times with short notes written about key points being made and with questions asked internally such as, 'What is the interviewee really saying? What points are made with this topic?' (Strauss & Corbin, 1990). The interview transcripts were coded via Grounded Theory's open coding which allowed for informative descriptors to be assigned to key phrases in the transcripts. Each of the codes was assigned to a matrix according to the research question asked and the interviewee. There were two different matrices for each research question: one for suborbital space companies and the other for Purdue's astronaut alumni. Once the codes were assigned to their respective matrices, common themes were found among interviewees. The final step of data analysis was to make assertions based upon the data gathered. The assertions made with regard to the research questions were compiled to create a strength of the continuum. The strength of the code was determined by the researcher using the code's location within the transcript, relations to the context in which the code was mentioned, the emphasis placed upon the code itself by the interviewee and via the researcher listening to the audio recording of the interviewee's tone and inflection when the particular code was said (Strauss & Corbin, 1990).

Researcher Bias

I am a graduate of Purdue's College of Science with Bachelor of Science degrees in Applied Physics (2007), Interdisciplinary Science (2008) and a Master of Science degree in Aviation and Aerospace Management (2010). I am a FAA certified private pilot with approximately 220 hours of Pilot-in-Command time with an additional 200 hours in FAA approved flight training devices. I have read the biographies and autobiographies of most of the 24 astronauts who journeyed to the Moon as well as those key personnel within NASA during the Apollo Program. The most influential book that I have read for this research project was *Deke!*, written by Deke Slayton, who was one of NASA's first astronauts. During his tenure at NASA, Slayton was responsible for the selection of new astronauts from the mid 1960s to the late 1970s and he selected the crews for all of the Gemini and Apollo missions.

Findings and Assertions

Research Question 1: What kind of educational and/or technical background should a commercial astronaut possess?

Assertion: A commercial astronaut should have an engineering degree at the Bachelor's level or higher.

Definition: an engineering degree is a broad term that could be any sub discipline of engineering as it relates to aerospace such as aeronautical, astronautical, electrical, mechanical or materials engineering. A bachelor's degree is minimal amount of educational knowledge required with preference given to advanced degrees.

> "As it comes to educational requirements, I would say an engineering degree at least as a Bachelor's" (NASA Astronaut A, personal communication, 2010)
>
> "So for educational and technical background whatever the requirements are for military pilots along the lines of engineering training or possibility some classes either undergraduate or master degree level" (NASA Astronaut B, personal communication, 2010)

Research Question 2: What type and how much flight experience should a commercial astronaut have?

Assertion: A commercial astronaut should have a test pilot background.

Definition: A test pilot is someone who flies new and experimental aircraft during the first few flights to verify the design specifications of the vehicle. Furthermore, they 'push the limits' of the vehicle to determine the margins of safety for commercial or military use. A test pilot is also familiar and comfortable with high stress situations associated with testing new, unproven vehicles.

> "Generally those type of vehicles are not going to have enough experience behind them to be routine so people with flight test experience [would] probably be more appropriate for piloting those vehicles" (Suborbital Space Company Representative B, personal communication, 2010).

"Because of the big unknowns right now, you are going to want test pilots" (NASA Astronaut C, personal communication, 2010)

Assertion: A commercial astronaut should have thousands of hours as Pilot-in-Command (PIC) of high performance jet aircraft (The FAA and the airline industry use the term PIC as time accumulated by a pilot in command of the aircraft even though the autopilot may be used for the majority of the flight. In this definition, PIC time refers to only hand flown time)
Definition: a high performance jet aircraft is a single or multi turbine engine aircraft similar in performance and maneuverability to state-of-the-art military fighters. PIC time is actual pilot control of the aircraft with no autopilot use.

"I think commercial astronauts, the ones actually flying the vehicle, should have to have the same requirements that NASA astronauts have. And that would be a minimum of 1000 hours pilot in command time" (NASA Astronaut D, personal communication, 2010).

"Somewhere around the order of several thousand hours, probably around two thousand hours in a high performance jet aircraft or a thousand minimum that you would need to have before you had somebody climb into a rocket expecting them to fly passengers to space" (NASA Astronaut B, personal communication, 2010).

Research Question 3: In terms of personality and character, what would make a desirable commercial astronaut?

Assertion: A commercial astronaut should have strong communication skills.
Definition: communication skills are the ability to document and transmit information verbally or via writing. The ability of a pilot to relate a wrong 'feel' of an aircraft to a technician who can fix the problem is extremely important.

"You've got to be able to work with the engineers and technicians who are developing the spacecraft to be able to, when they find something that needs to be fixed, they need to be able to communicate why it needs to be fixed and work with the people involved to get it fixed" (NASA Astronaut C, personal communication, 2010).

"The ability to communicate phases of flight and the willingness to communicate all of the phases of flight and explain to them what to expect and give them [the passengers] a couple of updates about the way things are going" (NASA Astronaut B, personal communication, 2010).

Assertion: A commercial astronaut should have enormous confidence in his/her vehicle and training and should inspire confidence in his/her passengers.
Definition: the space tourism industry is an emerging market with cutting edge technology and experimental vehicles. In order to successfully operate a spacecraft for passenger revenue flights, a commercial astronaut needs to to be confident in his/her vehicle's design and testing as well as in his/her own abilities to fly the spacecraft safely.

"[It is a] brand new industry and it is a brand new experience for these folks and so that level of confidence of the flight crew would be critical and so to me that would say being able explain the engineering of the vehicle in the flight, the propulsion, the electrical systems and the ascent environment and the technical perspectives and should be able to explain it and comment everything about it would be an absolutely critical part of the experience that these folks would have" (NASA Astronaut A, personal communication, 2010).

"That is because they are flying people in space who are probably paying per seat in that sense the crew needs to be like a boat captain or cruise director" (NASA Astronaut B, personal communication, 2010).

Assertion: The commercial astronaut should be humble as it pertains to his/her personality and work.
Definition: being humble means having the ability to admit mistakes and learn from them, the ability to take constructive criticism well and the ability to 'check your ego' before piloting a suborbital spacecraft.

"Throw away the scarf" (NASA Astronaut A, personal communication, 2010).

"I think they ultimately want someone that can check their ego at the door and work effectively in a team environment" (Suborbital Space Company Representative C, personal communication, 2010).

Research Question 4: If training a person to become a commercial astronaut, what are the most important subjects and/or flight areas in which to be familiar?

Assertion: The commercial astronauts should have a fundamental understanding of their spacecraft's engineering, performance characteristics and limitations.
Definition: information about the specific handling characteristics of the spacecraft as it pertains to G limitations, aerial maneuvers, landing speed, maximum bank angle, etc.

"It would be more of a familiarization with the vehicle. That's important" (NASA Astronaut D, personal communication, 2010).

"Things like engine operation/thrust, flight trajectory (up and down), flight path angle, "zero g" characteristics, heating, flight control response throughout the flight regime, and of course, landing procedures, would be topics of interest" (NASA Astronaut E, personal communication, 2010).

Assertion: The commercial astronaut should be familiar with emergency procedures of the vehicle.
Definition: an emergency procedure is an event that is off-nominal, unplanned or otherwise dangerous to the safety of the vehicle.

"Also the flight simulation and emergency procedures that would have to be taught and learned" (NASA Astronaut D, personal communication, 2010).

"But for the spacecraft it would be some kind of really dangerous spin or a pressurization, something like that. Which you really wouldn't want the real person to go through because they have to learn. You don't want them to kill themselves" (NASA Astronaut C, personal communication, 2010).

Assertion: The commercial astronaut should be trained in spacecraft trajectories during launch, ascent, cruise, entry and landing.
Definition: suborbital spaceflight is unique when compared to traditional aircraft due to the high speeds, altitudes, maneuvers performed and power of the vehicle. Key parts of understanding the new kind of flight environment are astronautics, physics and aeronautic engineering.

"So most of the training will have to revolve around the trajectories itself and the attitudes, G loads of those trajectories and then the handling of the flight control systems during ascent and entry and then the off-nominal, potential off-nominal scenarios around all that" (NASA Astronaut A, personal communication, 2010).

"Flying rockets is a completely unique environment" (Suborbital Space Company Representative C, personal communication, 2010).

Research Question 5: When selecting a commercial astronaut, is there anything that you believe is important to consider that we have not discussed?
Assertion: A commercial astronaut is not needed for some spacecraft operations.
Definition: Armadillo Aerospace is designing and building their *Black Armadillo* suborbital spacecraft to operate as a fully automated vehicle. There would be no flight crew members aboard the vehicle during tourist flights.

"The Armadillo Aerospace vehicle concepts require no crew as such. They are designed to be autonomous in virtually all respects except for the launch controllers and pad ops team. There will be no pilot, commander...or beverage service when we reach cruising altitude :-)" (Suborbital Company Representative A, personal communication, 2010)

Summary of Findings

The assertions made about a commercial astronaut are that he/she: should have at least a Bachelor's degree in engineering, have a test pilot background with thousands of hours of PIC time in high performance jet aircraft, be confident yet humble in personality and have an in-depth knowledge of their spacecraft, including emergency procedures and spacecraft trajectories.

Discussion

The results of this study may be hard to generalize to the commercial space tourism industry due to the uniqueness of each company's spacecraft design. Also, the participants of this study, n=11, represent a small portion of the individuals who have flown in space and who are actively working to develop suborbital spacecraft. In addition, the space tourism industry is yet unproven and highly experimental. The only U.S.-based suborbital space company to operate a suborbital spacecraft was Scaled Composites with three spaceflights of SpaceShipOne in 2004. The spacecraft being developed have been experimental vehicles with little or no previous experience in actual suborbital spaceflight. This could cause the initial selection criteria of suborbital commercial astronauts to be much higher right now as opposed to when the industry becomes more established. Several of the interviewees shared these thoughts.

> "I believe the initial requirements will differ from the later ones when (if) the business becomes established" (Suborbital Space Company Representative C, personal communication, 2010).

> "The qualifications right now will be much higher than they will be in say 10 years...Right now, there are very few slots and the competition is very fierce and there are huge numbers of unknowns. So all of those are going to drive all of these requirements very high right now" (NASA Astronaut C, personal communication, 2010).

Recommendations

Although the results of this exploratory study suggest that the suborbital commercial astronauts should have a strong background in engineering, flight test experience and have strong personable skills, further studies may be conducted to strengthen the results. A larger sample of participants for the next study may be needed. It is the researcher's recommendation to use this study as a basis for further research into the area of commercial astronaut selection. Future research should also investigate a possible training guide for commercial astronauts to prepare themselves at the university level for careers as commercial astronauts. Many of these research topics and questions can only be answered once the space tourism industry is established. There is need for additional research into this emerging industry and this study provides the basis for it with regard to commercial astronaut selection.

Additional information can be found in Brian Kozak's 2010 Thesis 'The Selection of Commercial Astronauts for Suborbital Spaceflight', Purdue University. I can be reached at bkozak@purdue.edu

References

Ansari X-Prize Foundation (2010). *Ansari_x_prize.* Retrieved from http://space.xprize.org/ansari-x-prize

Borman, F. (1988). *Countdown*. New York, NY: Silver Arrow Books.

Cernan, E. (1999). *The last man on the moon*. New York, NY: St. Martin's Press.

Clark, P. (1988). *The Soviet manned space program.* New York, NY: Orion Books.

Federal Aviation Administration Office of Commercial Space Transportation (2010). *2010 U.S. commercial space transportation developments and concepts: vehicles, technologies, and spaceports.* Retrieved from http://www.faa.gov/about/office_org/headquarters_offices/ast/media/ast_developments_concepts_2010.pdf

Freeman, M. (2000). *Challenges of human space exploration.* Cornwall, United Knigdom: Praix Publishing.

Gagarin research & test Cosmonaut training center: Cosmonaut training and testing (2008). Retrieved from http://www.gctc.ru/eng/index.html

Glaser, B. & Strauss, A. (1967). *The discovery of grounded theory*. Chicago, IL: Aldine Publishing Company.

Harvey, B. (2004). *China's space program: from conception to mannedspaceflight*

Linenger, J. (2000). *Off the planet*. New York, NY: McGraw-Hill.

Messerschmid, E., Haignere, JP., Damian & K., Damann, V. (2003). *European astronaut centre prepares of international space station operations*. Science Direct.

NASA. (1963). *Project mercury astronaut selection overview*, Retrieved from http://www.nasa.gov/mission_pagesmercury/missions/astronaut.html

Patton, M.Q. (2002). *Qualtative research and evaluation methods (3rd ed.)*. Thousand Oaks, CA: Sage Publications Inc.

RKA. (2009). *Russian federal space agency.* Retrieved from http://www.roscosmos.ru/fsa_naprav.asp?

Rutan, B. (12-January-2007). *Entrepreneurs are the future of space flight*. TED Conference. Long Beach, CA.

Scaled_composites. (2010). Retrieved from http://www.scaled.com/projects/tierone/

Sekaran, U. (2003). *Research methods for business: A skill building approach.* New York John Wiley & Sons Inc.

Shepard, A. (1994). *Moon shot*. Atlanta, GA: Turner Publishing.

Slayton, D. (1994). *Deke!* New York, NY: Forge Books.

Smith, A. (2005). *Moondust.* New York, NY: HarperCollins Publishers.

Strauss, A. & Corbin, J. (1990). *Basics of qualative research.* Newbury Park: Sage Publications Inc.

Wiggins, M.W (1999). *Aviation social science: Research methods in practice*. Aldershot, United Kingdom: Ashgate. New York: Praix Publishing.